A YOKE STRUCTURE WITH A STEP

FIELD OF THE INVENTION

The invention relates to a write head having a planar top yoke which includes a second pole tip region at the ABS that is thinner than the backside region of the top yoke and in particular to a second pole tip region with a step that controls the flux flow and reduces the leakage field at the second pole tip.

BACKGROUND OF THE INVENTION

A magnetic disk drive includes a rotating magnetic disk with circular data tracks and read and write heads that may form a merged head which is attached to a slider on an arm which positions the head. During a recording operation, the merged head is suspended over the magnetic disk on an air bearing surface (ABS). The write head has first and second pole pieces that are connected at a back gap region. The first and second pole pieces or yokes have first and second pole tips, respectively, that are separated by a write gap layer and terminate at the ABS. An electric current is passed through coils formed around the back gap region to magnetize the first and second pole pieces. As the leading first pole tip is moved over a magnetic disk, a magnetic flux passes from the second pole tip onto a data track and then to the first pole tip and is called the gap field.

A trend in the industry is to increase the recording density which requires increased coercivity to overcome the demagnetization field of the magnetic transition. However, as the data track width shrinks, the write head field strength tends to decrease due to

saturation of the second pole tip region. Unfortunately, a high-end hard disk drive (HDD) generates such a high data rate transfer that not only is greater write head field strength required, but a faster flux rise time is needed. To produce a large enough overwrite value, the write current is boosted and a large overshoot of its waveform results. This condition causes severe excess saturation of the second pole tip and adjacent track erasures often occur.

A conventional planar write head **10** is depicted in FIG. 1 and features a bottom yoke or first pole piece **2** formed on a substrate **1** which may be ceramic, for example. There is a planar top yoke or second pole piece **3** that is connected to the bottom yoke **2** through a back gap region **4** and which is covered by an overcoat layer **14**. The bottom yoke **2** has a pedestal **5** with a first pole tip **7** and a throat region **6**. The top yoke **3** has a second pole tip region **3a** that terminates at a second pole tip **8** at the ABS. The throat region **6** and second pole tip region **3a** are separated by a write gap layer **9** which is non-magnetic and extends from the ABS toward the back gap region **4** by a distance **TH** which is the throat height. At this point, the bottom yoke **2** begins to separate from the top yoke **3** and forms a cavity with sidewalls and a bottom. A conformal first dielectric layer **11** is formed on the sidewalls and bottom of the cavity. A coil layer **13** is wrapped between the top yoke **3** and bottom yoke **2** and around the back gap region **4** and is contained in a second dielectric layer **12** which is coplanar with the top of the write gap layer **9**. This design enables the top yoke **3** to be formed on a planar surface to allow good track width control for the second pole tip **8** definition. In a merged head design, the bottom yoke **2** of the write head also serves as the top layer of the read head (not shown).

Referring to FIG. 2, a top-down view of the write head **10** is depicted in which the overcoat layer **14** and dielectric layers **11**, **12** have been removed to show the arrangement of the top yoke **3**, bottom yoke **2**, back gap region **4**, and coil layer **13**. The top yoke **3** has a length $\mathbf{d_1}$ of about 5 to 25 microns which includes the length $\mathbf{d_2}$ of the second pole tip region **3a**. The maximum width of the top yoke **3** and bottom yoke **2** is $\mathbf{w_1}$. The main body of the top yoke **3** behind the second pole tip region **3a** is also referred to as the back side region.

Referring to FIG. 3, a side view from the plane **15-15** in FIG. 1 is shown that depicts the second pole tip region **3a** and the second pole tip **8** at the ABS end of the top yoke. The write gap layer **9** overlays the first pole tip **7** and the pedestal **5**. The second dielectric layer **12** is on either side of the write gap layer **9** and pedestal **5** at the ABS while the second pole tip region is surrounded on the top and sides by the overcoat layer **14**.

In a conventional planar writer shown in FIG. 4 which is an enlarged view of the ABS end of write head **10** in FIG. 1, the top yoke **3** can provide a significant amount of flux **16** toward the write gap layer **9**. The flux **16** passes from the second pole tip region **3a** through the second pole tip **8** onto a recording track (not shown) and then through the first pole tip **7** and into pedestal **5**. However, there is some leakage represented by a flank field **17** across the ABS onto an adjacent recording track. When a high write current is employed with large overshoot waveforms, then a significant amount of erasure on adjacent data tracks occurs because of the flank field. Therefore, a new write head design is needed that reduces the flank field to prevent unwanted data track erasure.

In U.S. 6,473,276, a merged magnetic head which includes a write head with a single sided notched first pole piece is described. A data track is formed that has a narrow erase band on one side and a wide erase band on the other side. The narrow erase band enables a large signal amplitude while a wide erase band allows flexibility in spacing the read head from adjacent tracks.

A magnetic write head with a zero throat height (ZTH) layer is disclosed in U.S. Patent 6,111,724. The ZTH is formed close to the first and second pole tips to reduce flux loss between the first and second pole pieces. The method of forming the ZTH layer avoids reflective notching and thereby improves definition of the second pole tip.

Another second pole piece is described in U.S. Patent 6,337,783 where a second yoke component is stitched to the back and sides of the top edge of a second pole tip to provide improved magnetic coupling. The top stitched area is minimized so that the coil layers may be closer to the ABS to increase the data rate of the head. In related art disclosed in U.S. Patent 6,029,339, the stitching of the yoke component to the second pole tip is achieved by a method that avoids reflective notching in the top yoke.

Unwanted side writing is prevented in U.S. Patent 6,504,675 by modifying the second pole tip such that the leading edge of the pole tip is narrower than the trailing edge. Thus, the second pole tip has a trapezoidal cross-section with tapered sides.

SUMMARY OF THE INVENTION

One objective of the present invention is to provide a planar top yoke in a write head that reduces the flank field at the ABS.

A further objective of the present invention is to provide a planar top yoke in accordance with the first objective that does not reduce the gap field strength for writing a data track.

These objectives are achieved in a first embodiment with a write head which includes a top planar yoke comprised of second pole tip region and a backside region. The backside region has a front section adjacent to the back end of the second pole tip region as viewed from the ABS plane. The front end of the second pole tip region is the second pole tip formed along the ABS. The top planar yoke is connected to a bottom yoke through a back gap region. The bottom yoke has a pedestal with a short throat region and a first pole tip formed at the ABS. The throat region and second pole tip region are separated by a write gap layer. In one embodiment, the top of the write gap layer is coplanar with the top of a cavity formed between the top and bottom yokes. The cavity has sidewalls and a bottom which is filled with a dielectric layer and extends from the throat region to the back gap region and beyond. Enclosed within the dielectric layer is a coil layer which surrounds the back gap region. An insulating overcoat layer is located on the planar top yoke.

The second pole tip region has a first thickness, a first width, two sides, a top and bottom, a back end that connects to the front end of the backside region, and a front end formed along the ABS. The backside region of the top yoke has a second thickness greater than the first thickness, a top and bottom, and includes a front section adjacent to the second pole tip region that flares outward and becomes wider with increasing distance from the second pole tip region. A key feature is that the top of the second pole tip region forms a step down toward the ABS from the front section of the

top yoke. The second pole tip region has a length of about 0.2 to 2 microns from the ABS to the front end of the backside region of the top yoke.

The bottoms of the second pole tip region and backside region are coplanar with the top of the write gap layer. The sides of the second pole tip region and backside region are perpendicular to the plane containing the top surface of the write gap layer. This design causes the magnetic flux from the backside region of the top yoke to pass through the second pole tip region with a tilted angle toward the bottom or so-called gap side near the ABS. As a result, the flux is concentrated on the gap side of the second pole tip region and a lower flux density near the top of the second pole tip region minimizes the magnitude of the flank field.

In a second embodiment, the planar write head is comprised of the same components as described in the first embodiment. The second pole tip region has a first thickness, a first width, two sides, a top and bottom, a back end that connects to the front section of the backside region, and a front end or second pole tip formed along the ABS. However, the front section of the backside region is comprised of two segments with different thicknesses that form a second step. A first segment of the front section has a second thickness greater than the first thickness, two sides, a top and bottom, a back end that connects to the front end of a second segment, and a front end adjacent to the back end of the second pole tip region. The second segment of the front section has a third thickness greater than the second thickness and includes two sides, a top and bottom, and a front end adjacent to the back end of the first segment. The second segment has the same thickness as the main body of the top yoke in the backside region. The first segment represents a step down from the second segment toward the

ABS and the second pole tip region is a step down from the first segment toward the ABS.

The bottoms of the first and second segments and the second pole tip region are coplanar with the top surface of the write gap layer. The sides of the first and second segments and of the second pole tip region are perpendicular to the plane containing the top surface of the write gap layer. This design causes the magnetic flux from the backside region of the top yoke to pass through the first and second segments of the front section with a tilted angle toward the bottom or so-called gap side of the second pole tip region. As a result, there is a higher flux density in the second pole tip region near the write gap layer at the ABS and a lower flux density near the top of the second pole tip region that minimizes the magnitude of the flank field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view showing a conventional planar write head with a top yoke comprised of a second pole tip region that has the same thickness as the planar top yoke.

FIG. 2 is a top-down view of a conventional planar write head that depicts the shape of the planar top yoke and its relationship to the ABS and underlying coil layer.

FIG. 3 is a cross-sectional view from ABS that shows the second pole tip, first pole tip, and write gap layer of the prior art planar write head depicted in FIG. 1.

FIG. 4 is an enlarged view of pole tip regions in FIG. 1 that indicates a large flank field near the second pole tip in addition to the gap field used for recording.

FIG. 5 is a cross-sectional view of a write head with a planar top yoke that has a second pole tip region which forms a step near the ABS according to the present invention.

FIG. 6 is a cross-sectional view from the ABS of the write head structure in FIG. 5 that depicts a second pole tip region with a smaller thickness than the backside region of the top yoke.

FIG. 7 is a top-down view of the write head structure in FIG. 5 showing the shape of the second pole tip region and backside region of the top yoke.

FIG. 8 is an enlarged view of the pole tip regions in FIG. 5 which indicates a reduction in size of the flank field compared to the flank field in FIG. 4.

FIG. 9 is a cross-sectional view of a write head with a planar top yoke that has two steps from the backside region toward the ABS according to a second embodiment of the present invention.

FIG. 10 is a cross-sectional view from the ABS of the write head structure in FIG. 9 that depicts a smaller thickness in second pole tip region than in two segments of a backside region.

FIG. 11 is a top-down view of the write head structure in FIG. 9 that shows the shape of the second pole tip region and backside region.

FIG. 12 is an enlarged view of the pole tip regions in FIG. 9 which indicates a reduction in size of the flank field relative to the flank field in FIG. 4.

FIG. 13a is a plot that shows flank field magnitude as a function of down track position for a conventional planar write head while FIG. 13b is a plot that indicates a smaller flank field with the stepped top yoke of the present invention.

FIG. 14 is a plot that shows the ratio of flank field to gap field as a function of the size of the recess in the step in the top yoke of the first embodiment.

FIG. 15 is a plot which shows the ratio of flank field to gap field vs. the ratio of the thickness of the second pole tip region to the thickness of the backside region according to the first embodiment of the present invention.

FIG. 16 is a plot which shows the ratio of flank field to gap field as a function of the combined recessed length of the two steps in the top yoke of the second embodiment.

FIG. 17 is a plot that shows the ratio of flank field to gap field vs. the ratio of the thickness of the second pole tip region to the thickness of the backside region according to the second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a planar write head with a top yoke that is designed to direct magnetic flux during a write operation toward the gap side of a thinner second pole tip region in order to minimize a flank field. The drawings are provided by way of example and are not intended to limit the scope of the invention. Additionally, the figures are not necessarily drawn to scale and the relative sizes of the various elements may be different than in an actual write head.

A first embodiment is set forth in FIGS. 5 – 8 in which a key feature is a planar top yoke comprised of a backside region and a second pole tip region that forms a single step near the ABS. Referring to FIG. 5, a planar write head **20** is shown that is part of a magnetic disk drive. Typically, the write head **20** is held by an arm (not shown) and is suspended over a rotatable magnetic disk on an air bearing surface (ABS) when writing

a data track. It is important that during a writing operation the write head does not erase adjacent data tracks. According to the present invention, the shape of the write head is designed to minimize a flank field to prevent unwanted erasures.

The write head **20** is comprised of a first pole piece or bottom yoke **22** that is formed on a substrate **21**. In one embodiment, the substrate **21** is a non-magnetic material such as ceramic. Optionally, the write head may be part of a merged head design in which the bottom yoke **22** also serves as the top layer in a read head (not shown). The bottom yoke is connected to a second pole piece or top yoke **23** through a back gap region **24**. The length of the top yoke **23** from the ABS to the back gap region is about 5 to 25 microns. The bottom yoke **22**, top yoke **23**, and back gap region **24** may be comprised of a ferromagnetic material such as NiFe or permalloy or may be a material with a high magnetic moment such as CoNiFe, FeCo, or FeCoN. The bottom yoke **22** has a pedestal **25** with a short throat region **26** and a first pole tip **27** which is the surface that is formed along the **ABS**.

The planar top yoke **23** has a narrow front section **32a** and a second pole tip region **32b** which have a combined length $\mathbf{d_3}$ of about 1 to 3 microns from the **ABS** toward the back gap region **24**. A key feature of the present invention is that the second pole tip region **32b** which terminates at the second pole tip **33** along the **ABS** is thinner than the front section **32a** and forms a step down from the front section toward the write gap layer **34**. The front section **32a**, second pole tip region **32b**, and remainder of the top yoke **23** form a single piece. The second pole tip region **32b** and throat region **26** are separated by a write gap layer **34** having a thickness of about 0.08 to 0.14 microns which extends from the **ABS** to a distance **x** of about 0.4 to 1.2 microns toward the back

gap region **24**. Typically, the write gap layer **34** is comprised of a non-magnetic material such as Al_2O_3, silicon oxide, NiCu, Ru, or Pd. It is understood that the second pole tip region **32b** and pedestal **25** are comprised of the same material as in the top yoke **23** and bottom yoke **22**.

In one embodiment, there is a cavity formed between the bottom yoke **22** and top yoke **23** that extends from the short throat region **26** to behind the back gap region **24**. There is a dielectric layer **29** formed on the bottom yoke **22** which fills the cavity and has a top surface that is coplanar with the write gap layer **34**. Alternatively, there may be more than one dielectric layer in the cavity. Within the dielectric layer **29** is a coil layer **30** that is wrapped around the back gap region **24**. Optionally, more than one coil layer may be employed. The dielectric layer **29** is typically comprised of alumina, silicon oxide, silicon nitride, or a resin. The coil layer **30** includes a plurality of coils which are generally comprised of Cu or Au. An overcoat layer **35** is formed on the top yoke **23** and back gap region **24** and is preferably a dielectric layer comprised of alumina or silicon oxide.

Referring to FIG. 6, a cross-sectional view of the write head **20** from the plane **36-36** in FIG. 5 is depicted. The second pole tip region **32b** has a width $\mathbf{w_2}$ of about 0.1 to 0.25 microns and a thickness $\mathbf{t_1}$. The front section **32a** of the top yoke is recessed behind the second pole tip region **32b** and has a thickness $(\mathbf{t_1} + \mathbf{t_2})$, and a width that is typically larger than $\mathbf{w_2}$. Moreover, the width of the front section **32a** typically increases with increasing distance from the ABS. The thickness $\mathbf{t_1}$ is preferably in the range of about 0.4 to 1.2 microns and the thickness $\mathbf{t_2}$ is preferably about 0.4 to 1.8 microns. The top surface of the front section **32a** is an extension of the top surface of the top

yoke **23.** The front section **32a** also has two sides (not shown) which flare outward as the distance behind the ABS increases, a front end that is adjacent to the back end of the second pole tip region **32b**, and a back end that is connected to the front end of the back section of the top yoke **23**. The bottoms of the first section **32a** and the second pole tip region **32b** are coplanar with the write gap layer **34**. The second pole tip region **32b** has two sides that are perpendicular to the top surface of the write gap layer **34**, a back end, and a front end or second pole tip **33** that is coplanar with the ABS.

An important aspect of the present invention is that the second pole tip region **32b** is thinner than the front section **32a**. In particular, the top of the second pole tip region **32b** is stepped down from the top of the front section **32a** so that a step is formed from the top yoke **23** toward the **ABS**. In a preferred embodiment, the width $\mathbf{w_2}$ of the second pole tip region **32b** is equal to the width $\mathbf{w_3}$ of the write gap layer **34**, pedestal **25**, and the first pole tip **27**.

A top-down view of the top yoke **23** portion of the write head structure **20** is shown in FIG. 7. Note that the front section **32a** is narrower than the larger back section **28**. The front end of the front section adjacent to the second pole tip region **32b** has a smaller width than the back end which is connected to the back section **28** at a distance $\mathbf{d_3}$ from the ABS.

Referring to FIG. 8, an enlarged view of the write head **20** near the **ABS** shows that the second pole tip region **32b** extends from the **ABS** to the front section **32a** which is a distance $\mathbf{d_4}$ of about 0.2 to 2 microns and preferably about 0.3 to 1 microns. In other words, the step in the top yoke **23** extends a distance $\mathbf{d_4}$ from the **ABS** toward the back gap region. When a current is applied to the coil layer **30**, a magnetic flux **37** is

generated in the top yoke **23** that passes through the front section **32a** and is directed toward the bottom (gap side) of the second pole tip region **32b** and through the second pole tip **33**. In so doing, a weaker flux density is formed near the top of the second pole tip region **32b**. As a result, the flank field **38** is significantly less than observed in prior art planar writers such as illustrated in FIGS. 1 – 4. The gap field is defined as the flux **37** which passes from the second pole tip **33** through the intended magnetic recording track (not shown) adjacent to the **ABS**. The flux **37** then passes from the recording track through the first pole tip **27** and into the pedestal **25**. The thickness (**t1** + **t2**) of the front section **32a** and top yoke **23** may be adjusted upward to increase the gap field while maintaining the flank field **38** at an acceptable low level.

One advantage of implementing the first embodiment of the present invention is illustrated in FIGS. **13a** – **13b** in which the flank field **37** is estimated as the maximum in-plane field at the magnetic disk surface at each down track position from the write head for a conventional head (curve **50**) and for the write head with a stepped top yoke (curve **51**). The results represented by curve **51** were generated with a $\mathbf{t_1}$ thickness of 0.7 microns, a $\mathbf{t_2}$ thickness of 0.8 microns, and a $\mathbf{d_4}$ distance of 0.6 microns. The starting position at 0 microns in FIGS. 13a, 13b is defined as the bottom of the second pole tip region at the ABS where the second pole tip meets the write gap layer. Increasing x-values represent down track positions progressively farther away from the starting position. The write head of the present invention generates a smaller flank field, especially at down-track positions of greater than about 0.3 microns. Note the rapid drop in flank field intensity (oersteds) for curve **51** between the 0.3 and 1 micron down track positions. As mentioned previously, another advantage of the present invention is

that a strong gap field can be achieved while keeping the flank field at a low intensity that avoids track erasure.

The influence of the size of the recess $\mathbf{d_4}$ on the ratio of flank field to gap field has been characterized and is illustrated in FIG. 14. A conventional planar write head where the recess is 0 microns has a flank field/gap field ratio of about 28%. The inventor has found that the flank field/gap field ratio is decreased to about 20% or less by introducing a recess of 0.3 to 1 microns. However, a recess as small as 0.2 microns or as large as 2 microns also offers some benefit.

Referring to FIG. 15, the present invention has been further characterized by determining the effect of the step height $\mathbf{t_1}$ as shown in FIG. 6 on the flank field/gap field ratio. The values on the x-axis represent the ratio $\mathbf{t_1/(t_1 + t_2)}$ and indicate the largest reduction in flank field occurs when the thickness ratio is between 0.3 to 0.7. The results shown in FIG. 15 were generated with a $\mathbf{t_1}$ thickness of 0.7 microns, a $\mathbf{t_2}$ thickness of 0.8 microns, and a $\mathbf{d_4}$ distance of 0.6 microns.

Those skilled in the art will appreciate that a step in the top yoke of the present invention may be readily constructed by conventional methods. For example, a first yoke layer with a thickness $\mathbf{t_1}$ may be formed on the dielectric layer **29** by conventional means. Then a second top yoke layer with a thickness $\mathbf{t_2}$ is fabricated on the first top yoke layer by a process sequence involving deposition, patterning, ion etching, and trim milling methods known to those skilled in the art. The second top yoke layer is recessed from the ABS to form a first step.

The present invention also anticipates a write head with a planar top yoke that has a plurality of steps near the ABS. In the exemplary second embodiment depicted in FIGS.

9 - 12, the top yoke has a second pole tip region that represents one step and an adjacent segment in the front section of the top yoke that represents a second step.

Referring to FIG. 9, the write head **20** is comprised of the same components as described in the first embodiment. The write head **20** may be part of a merged head design in which the bottom yoke **22** also serves as the top layer in a read head (not shown). Alternatively, the bottom yoke **22** may be formed on a non-magnetic substrate **21** such as a ceramic. The planar top yoke **23** has been modified to include two steps. There is a second pole tip region **40c** and an adjacent front section of the top yoke **23** comprised of two segments **40a**, **40b**. The combined length $\mathbf{d_5}$ of the second pole tip region **40c** and front section is the distance from the **ABS** to the back end of the segment **40a**.

The first segment **40a** in the front section is coplanar with the larger back section of the top yoke **23**. The second segment **40b** in the front section forms a step down from the first segment **40a** toward the **ABS** and the second pole tip region **40c** forms a step down from the second segment toward the **ABS**. The first segment **40a**, second segment **40b**, and second pole tip region **40c** together with the top yoke **23** form a single piece.

Referring to FIG. 10, a cross-sectional view of the write head **20** from the plane **41-41** in FIG. 9 is depicted. The first segment **40a** in the front section of the top yoke is recessed behind the second segment **40b** and has a thickness ($\mathbf{t_3 + t_4 + t_5}$) and a width that is typically larger than the width $\mathbf{w_2}$. Note that the sides of the first segment **40a**, second segment **40b**, and second pole tip region **40c** are perpendicular to a plane that is formed by the interface of the overcoat layer **35** and dielectric layer **29** and contains

the top surface of the write gap layer **34**. Furthermore, the bottom of the first segment **40a**, second segment **40b**, and second pole tip region **40c** are coplanar with the top surface of the write gap layer **34**. The first segment **40a** has a back end that is connected to the front end of the back section in the top yoke and a front end adjacent to the back end of the second segment **40b**. The second segment **40b** has a width greater than $\mathbf{w_2}$, a thickness ($\mathbf{t_3} + \mathbf{t_4}$), a back end, and a front end that is adjacent to the back end of the second pole tip region **40c**. The second pole tip region **40c** has a width $\mathbf{w_2}$ of about 0.1 to 0.25 microns, a thickness $\mathbf{t_3}$, a back end, and a front end or second pole tip **33** that is coplanar with the **ABS**.

Preferably, the thickness $\mathbf{t_3}$ is about 0.4 to 1.2 microns, thickness $\mathbf{t_4}$ is about 0.2 to 1.4 microns, and thickness $\mathbf{t_5}$ is about 0.2 to 1.4 microns. An important aspect of the present invention is that the second pole tip region **40c** is thinner than the second segment **40b** which in turn is thinner than the first segment **40a**. In particular, the top of the second segment **40b** is stepped down from the top of the first segment **40a** and the top of the second pole tip region **40c** is stepped down from the top of the second segment. The preferred ratio of $\mathbf{t_3}/(\mathbf{t_3} + \mathbf{t_4} + \mathbf{t_5})$ is from 0.2 to 0.6 and the preferred ratio of $\mathbf{t_4}/(\mathbf{t_3} + \mathbf{t_4} + \mathbf{t_5})$ is from 0.2 to 0.6. In a preferred embodiment, the width $\mathbf{w_2}$ of the second pole tip region **40c** is equivalent to the width $\mathbf{w_3}$ of the write gap layer **34**, pedestal **25**, and the first pole tip **27**.

Referring to FIG. 11, a top-down view of the top yoke **23** portion of the write head structure **20** is shown. There is a larger back section **28** connected to the back end of the first segment **40a** of the front section of the top yoke at a distance $\mathbf{d_5}$ from the ABS.

The front end of the second segment **40b** adjacent to the second pole tip region **40c** has a smaller width than the front end of the first segment **40a**.

Referring to FIG. 12, an enlarged view of the write head **20** near the **ABS** shows that the second pole tip region **40c** extends from the **ABS** to the front end of the second segment **40b** which is a distance $\mathbf{d_7}$ of about 0.2 to 1.5 microns. The second segment **40b** extends from the back end of the second pole tip region **40c** to the front end of the first segment **40a** which is a distance $\mathbf{d_6}$ of about 0.2 to 1.5 microns. In other words, the first step down from the top yoke **23** is comprised of the second segment **40b** which has a back end that is recessed by the distance ($\mathbf{d_6} + \mathbf{d_7}$) from the **ABS.** The second step down from the top yoke **23** is comprised of the second pole tip region **40c** which extends a distance $\mathbf{d_7}$ from the **ABS**.

When a current is applied to the coil layer (not shown), a flux **37** is generated in the top yoke **23** that passes through the first segment **40a** and is directed toward the bottom of the second segment **40b** (gap side). Similarly, the flux **37** that passes through the second segment **40b** is directed toward the bottom (gap side) of the second pole tip region **40c** and through the second pole tip **33**. In so doing, a weaker flux density is formed near the top of the second pole tip region **40c** near the **ABS**. As a result, the flank field **38** is significantly less than observed in prior art planar writers such as illustrated in FIGS. 1 – 4. The flux **37** passes from the recording track through the first pole tip **27** and into the pedestal **25**. This design enables the thickness ($\mathbf{t_3} + \mathbf{t_4} + \mathbf{t_5}$) of the first segment **40a** and top yoke **23** to be adjusted upward to increase the gap field while maintaining the flank field **38** at an acceptable low level.

The same advantages are achieved in the second embodiment as described for the first embodiment. For instance, the flank field observed for a two stepped yoke as represented by curve **51** in FIG. 13b is decreased significantly at down-track positions compared with a flank field in a conventional planar writer (FIG. 13a). Thus, unwanted erasure of adjacent data tracks is prevented. Furthermore, a high gap field may be generated while controlling the flank field at a low level.

The influence of the size of the recess $\mathbf{d_6} + \mathbf{d_7}$ on the ratio of flank field to gap field has been characterized and is illustrated in FIG. 16. A conventional planar write head where the recess is 0 microns has a flank field/gap field ratio of about 28%. The inventor has found that the flank field/gap field ratio is decreased to about 20% or less by introducing two steps with $\mathbf{d_7}$ and $\mathbf{d_6} + \mathbf{d_7}$ recesses, respectively. The results shown in FIG. 16 were generated with a $\mathbf{t_3}$ 0.7 microns, a $\mathbf{t_4}$ thickness of 0.5 microns, and a $\mathbf{t_5}$ thickness of 0.5 microns.

Referring to FIG. 17, the present invention has been further characterized by determining the effect of the step thicknesses $\mathbf{t_3}$, $\mathbf{t_4}$, and $\mathbf{t_5}$ depicted in FIG. 10 on the flank field/gap field ratio. The values on the x-axis represent the ratio $\mathbf{t_3/(t_3 + t_4 + t_5)}$ and indicate the largest reduction in flank field occurs when the thickness ratio is between about 0.2 to 0.4. The results shown in FIG. 17 were generated with a $\mathbf{d_6}$ distance of 0.4 microns, and a $\mathbf{d_7}$ distance of 0.6 microns.

Those skilled in the art will appreciate that one or more steps in the top yoke of the present invention may be readily constructed by conventional methods. For example, a first yoke layer with a thickness $\mathbf{t_3}$ may be formed on the dielectric layer **29** by conventional means. Then a second top yoke layer with a thickness $\mathbf{t_4}$ is fabricated on

the first top yoke layer by a process sequence involving deposition, patterning, ion etching, and trim milling methods known to those skilled in the art. The second top yoke layer is recessed from the ABS to form a first step. Likewise, a third top yoke layer with a thickness t_5 may be formed on the second top yoke layer with a similar process sequence involving deposition, patterning, ion etching, and trim milling steps. The third top yoke layer has a larger recess from the ABS than the second top yoke layer and forms a second step.

While this invention has been particularly shown and described with reference to, the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of this invention.